What is claimed is:

1. A band filter, comprising:

a first waveguide grating router;

a second waveguide grating router; and

a plurality of waveguides connecting the first waveguide grating router to the second waveguide grating router;

wherein the connecting waveguides comprise one or more sets of waveguides and wherein the waveguides of each set are spaced at their connections to the first waveguide grating router such that optical signals having overlapping frequency ranges are propagated through adjacent waveguides and the waveguides of each set are spaced at their connection to the second waveguide grating router such that optical signals with predetermined optical frequency ranges are routed to selected, respective output ports.

2. The band filter of claim 1, wherein each set of waveguides contains two or more waveguides having path lengths that are substantially equal to within a few wavelengths, and wherein the waveguides are spaced at their connection to each waveguide grating router such that the waveguides substantially spectrally perfectly sample or over-sample the waveguide grating routers.

3. The band filter of claim 1, wherein the connecting waveguides are positioned at their connections to the first waveguide grating router and the second waveguide grating router to optimize the low-loss propagation of optical signals within one or more predetermined optical frequency ranges.

4. The band filter of claim 1, wherein each of the sets of connecting waveguides are contiguous at their connection to the first waveguide grating router and have increased gaps between bands at their connection to the second waveguide grating router.

5. The band filter of claim 4, wherein output waveguides of the band filter are spaced by the size of the gaps of the connection to the second waveguide grating router minus one waveguide spacing, multiplied by the lensing magnification factor of the second waveguide grating router.

6. The band filter of claim 5, wherein the number of waveguide grating arms in the first waveguide grating router and the second waveguide grating router is substantially equal to or less than the number of connecting waveguides it takes to fill one diffraction order of the first or the second waveguide grating router.

7. The band filter of claim 4, further comprising dummy waveguides inserted in the gaps.

8. The band filter of claim 7, wherein the gaps between the bands of the connecting waveguides are substantially equal to an integer number of the connecting waveguides inlet spacing such that the dummy waveguides inserted in the gaps are able to make the mutual-coupling-induced aberrations for all connecting waveguide inlets substantially identical.

9. The band filter of claim 1, wherein the number of sets of connecting waveguides is equal to the number of bands an input signal is separated into by the band filter.

10. The band filter of claim 9, wherein said band filter comprises three sets of connecting waveguides and three output waveguides.

11. The band filter of claim 1, wherein said band filter is integrated onto a single planar lightwave circuit chip.

12. The band filter of claim 1, further comprising segmentation fibers on inner slab-to-waveguide-array junctions of the first and the second waveguide grating routers to reduce insertion loss.

13. The band filter of claim 1, wherein the connecting waveguides comprise a spectral sampling coefficient ranging from 1.07 to 1.01, from the shortest to the longest wavelength, respectively.

14. The band filter of claim 1, wherein said first waveguide grating router, said second waveguide grating router and said plurality of connecting waveguides are integrated on a single planar lightwave circuit.

15. A planar lightwave circuit, comprising at least two substantially identical band filters, such as the band filter of claim 11, constructed on a single chip.

16. The planar lightwave circuit of claim 15, wherein the size of the planar lightwave circuit chip is equal to 8.7 cm $\times$ 1.0 cm.

17. A band filter, comprising:

a first waveguide grating router;

a second waveguide grating router; and

a plurality of waveguides connecting the first waveguide grating router to the second waveguide grating router;

wherein the connecting waveguides are divided into sets and wherein the connecting waveguides have increased gaps between sets of waveguides at their connection to the second waveguide grating router to provide routing of optical signals with predetermined optical frequency ranges to selected, respective output ports.

18. The band filter of claim 17, wherein within each of the sets of connecting waveguides the waveguides are contiguous at their connection to the first waveguide grating router.